

## CORE STRUCTURE OF HEAT EXCHANGER

### BACKGROUND OF THE INVENTION

#### 5 1. FIELD OF THE INVENTION

The present invention relates to a core structure of corrugated fins of a heat exchanger having tubes through which coolant flows being fixed to seat plates, the core structure of corrugated fins used for a heat exchanger such as a radiator for a vehicle or the like.

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#### 2. DESCRIPTION OF THE RELATED ART

A core structure of a conventional heat exchanger is, for example, disclosed in Japanese Patent Laid-open No. Tokkaihei 11-14285 and in Japanese Patent Laid-open No. Tokkaihei 9-318292. This core structure of a  
15 conventional heat exchanger has sheet plates arranged opposite to each other with a predetermined space interposed therebetween, tubes and corrugated fins arranged alternately between the sheet plates, and reinforcements which couple and reinforce both end portions of the sheet plates.

20 FIG. 10 shows an example of the core structure of the conventional heat exchanger. As shown in FIG. 10, two sheet plates 101 are coupled and reinforced at their both end portions by reinforcements 104, and tubes 102 and corrugated fins 103 are alternately arranged between these sheet plates 101.

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Further, as shown in FIG. 11, on the sheet plates 101, tube holes 105 for fixing the tubes 102 by insertion and connection portions 106 having wall portions slanting toward the tube holes 105 are formed by burring.

30 On the other hand, in recent years, as the tubes 102, tubes having partitions 104 inside as shown in FIG. 12 have become the mainstream. Examples of these tubes are disclosed in Japanese Patent Laid-open No. 2002-303496 for

example.

Further, sheet plates and tubes in recent years are desired to be made thinner in order to improve a heat exchange rate of a heat exchanger.

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However, in the core structure of the conventional heat exchanger, when coolant flowing from an engine into a radiator rapidly changes in temperature from low to high as will be described later, large thermal expansion of the tubes 102 and the sheet plates 101 occurs, which may cause  
10 the connection portions 106 to press the tubes 102 to crack/break root portions of the tubes 102. This has been an obstruction to make the sheet plates 101 and the tubes 102 thinner.

Further, since the tubes 102 in which the partitions 104 are formed have a  
15 particularly small allowable amount of deformation against an external pressure, a countermeasure has been urgently needed against thermal stress applied by the connection portions 106 of the sheet plates 101 to the tubes 102.

20 Here, the rapid change of coolant flowing from an engine into a radiator in temperature from low to high occurs, for example, in a case that when an engine is started in a cold region, a state that coolant of the engine increases gradually in temperature but does not flow into a radiator continues until it reaches a valve-opening temperature of a thermostat, and then the  
25 temperature of the coolant becomes high to cause a valve of the thermostat to open, so that the coolant of high temperature flows into the radiator for the first time, or in a case that a so-called hunting phenomenon occurs such that a thermostat repeats opening and closing when driving in a cold region.

30 The present invention has been made in light of the above described problems, and an object thereof is to provide a core structure of a heat exchanger capable of preventing a crack and a breakage of root portions of

tubes fixed to sheet plates due to thermal stress of the sheet plates against the tubes when coolant flowing from an engine into a heat exchanger such as a radiator rapidly changes in temperature from low to high.

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## SUMMARY OF THE INVENTION

A core structure of a heat exchanger according to the present invention includes: tubes in which a heat exchange medium flows; corrugated fins adhering to the tubes to radiate heat from the heat exchange medium; and  
 10 sheet plates arranged opposite to each other with a predetermined space interposed therebetween and having the tubes and the corrugated fins arranged alternately therebetween, the sheet plates provided with connection portions having wall portions slanted with a predetermined slant angle from main body portions thereof toward the tubes and tube holes through which  
 15 the tubes are inserted to be fixed, in which when the tubes have a thickness of 0.13 mm to 0.23 mm, a slant angle  $\theta$  of the connection portions is:  
 slant angle  $\theta$  ( $^{\circ}$ )  $\geq 25 \times (\text{thickness (mm) of sheet plate}) + (-125 \times (\text{thickness (mm) of tube}) + 25)$

20 Therefore, in this core structure of the heat exchanger, the slant angle  $\theta$  of the connection portions is optimally set according to the thickness of the sheet plates and the thickness of the tubes so as to satisfy the above-described formula, so that cracking and breaking of the tubes due to thermal stress of the connection portions can be prevented as much as possible,  
 25 thereby allowing the sheet plates and the tubes to be made thinner.

Further, a correlation among the slant angle of the connection portions, the thickness of the sheet plates, and the thickness of the tubes can be comprehended using the above-described formula, so that development of  
 30 thinner sheet plates and tubes can be facilitated.

Furthermore, when a burring apparatus for forming the tube holes and the

connection portions is not able to form connection portions having a desired slant angle, a thickness of the tubes or the sheet plates which is optimum for a slant angle of connection portions formed by the burring apparatus can be set, so that thin tubes with better durability as compared to conventional tubes can be used.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

The objects, features and advantages of the present invention will become apparent as the description proceeds when taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a front view showing an entire core structure of a heat exchanger of an embodiment of the present invention;

FIG. 2 is an enlarged cross-sectional view of a part indicated by an arrow C in FIG. 1;

FIG. 3 is an enlarged perspective view of a sheet plate and so on in the part indicated by the arrow C in FIG. 1;

FIG. 4 is a cross-sectional side view taken along S4 to S4 in FIG. 3;

FIG. 5 is a view describing a slant angle of the connection portions;

FIG. 6 is a view showing results of thermal stress tests based on a relationship between the slant angle and stress;

FIG. 7 is a view showing results of heat and impact durability tests based on a relationship between the number of times of heat and impact durability tests and the slant angle;

FIG. 8 is a view showing a correlation between test results regarding combinations of various thicknesses of sheet plates 2 and tubes 3 and slant angles;

- 5 FIG. 9 is a view describing a slant angle at connection portions according to a second embodiment of the present invention;

FIG. 10 is a front view showing a core structure of a conventional heat exchanger;

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FIG. 11 is an enlarged cross-sectional view of a part indicated by an arrow V in FIG. 10; and

- 15 FIG. 12 is an enlarged plan view of the part indicated by the arrow V in FIG. 10.

### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

- 20 Hereinafter, embodiments of a core structure of a heat exchanger according to the present invention will be described.

Incidentally, in these embodiments, a case that the heat exchanger is an automotive radiator will be described.

- 25 As shown in FIG. 1, the core structure of a heat exchanger of a first embodiment of the present invention has a pair of sheet plates 2 and 2 arranged opposite to each other with a predetermined distance interposed therebetween at a top and bottom positions of a radiator 1.

- 30 Reinforcements 5 are arranged respectively at both end portions 2a of the sheet plates and couple the top and bottom sheet plates 2. Between the sheet plates 2 and the reinforcements 5, tubes 3 and corrugated fins 4 are

alternately arranged with a predetermined space interposed therebetween in a direction of the width of the radiator 1.

As shown in FIG. 2 to FIG. 4, on the sheet plates 2, tube holes 2b corresponding to arrangement positions of the respective tubes 3 are formed by burring. Incidentally, in FIG. 2 to FIG. 4, only top side portions of the sheet plates 2, the tubes 3, and so on are drawn and bottom side portions thereof are not shown. Regarding the bottom side portions, the bottom sheet plate 2 and the lower end portions of the tubes 3 are fixed in a vertically reverse state of the upper side portions.

As shown in FIG. 2, on main body portions 2h of the sheet plates 2, connection portions 2c having the tube holes 2b are formed with a predetermined space. The connection portions 2c have wall portions 2f in a cup shape slanted toward the tube holes 2b into which the tubes 3 are inserted from the main body portions 2h, and vulnerable portions 2d on side ends of the tube holes 2b of the wall portions 2f and vulnerable portions 2e on end portions of bottom portions 2g formed between the tube holes 2b are formed in series, respectively. These vulnerable portions 2d and 2e are thinner than the wall portions 2f which have the same thickness as that of the sheet plates 2 and formed with the wall portions 2f simultaneously at the time of burring.

The connection portions 2c function as a guide to insert a tip of the tube 3 into the tube hole 2b when the tubes 3 are assembled with the sheet plates 2, and when the sheet plates 2 thermally expand, the connection portions 2c act so as to absorb thermal stress of the connection portions 2c applied to the tubes 3 by bending of the vulnerable portions 2d and 2e.

In the tube holes 2b, both end portions 3c of the tubes 3 are fixed by brazes R1 in a state that the both end portions 3c are inserted therethrough.

Further, both end portions 5a of the reinforcements 5 are fixed by brazes R2 in a state that the both end portions 5a are inserted through reinforcement holes 5b formed in the sheet plates 2.

- 5 Incidentally, as shown in FIG. 4, on the outside of the sheet plates 2, a tank 8 is arranged with seals 9 interposed therebetween, and lower outer periphery portions 8a thereof are fixed to the sheet plates 2 by caulking.

10 Further, in this embodiment, the sheet plates 2, the tubes 3, the corrugated fins 4, and the reinforcements 5 are all made of aluminum and integrally assembled in advance, and thereafter they are brazed integrally in a not-shown heat treatment furnace.

15 Hereinafter, a slant angle of the connection portions 2c will be described using FIG. 5.

For the connection portions 2c of the first embodiment, a slant angle  $\theta$  becomes  $\theta = \tan^{-1} (LB/(LA/2))$  when a bottom portion 2g of the connection portions 2c at the center position of a distance LA between the adjacent  
 20 tubes 3 and 3 is an origin O, a distance in a horizontal direction from this origin O to the tubes 3 is LA/2, and a distance from the origin O to the highest positions of the connection portions 2c is LB, and the connection portions 2c are formed in a shape which satisfies the following relationship:  
 slant angle  $\theta$  (°)  $\geq 25 \times (\text{thickness(mm) of sheet plate}) + (-125 \times (\text{thickness}$   
 25  $(\text{mm) of tube}) + 25)$  ... formula 1

Incidentally, the thickness of the tube in the formula 1 is 0.13 mm to 0.23 mm for example.

- 30 Here, for example, in a first case of a combination of sheet plates (thickness: 1.3 mm) and tubes (thickness: 0.18 mm) made thinner than conventional ones, the connection portions 2c are formed to have a slant angle  $\theta$  of 35° or

larger by the formula 1.

Hereinafter, results of experiments performed regarding combinations of other sheet plates 2 and tubes 3 with various thicknesses including the first case will be described.

FIG. 6 shows measurement results of thermal stress received by the tubes when a slant angle  $\theta$  of each connection portion 2c is varied regarding the combinations of other various sheet plates 2 and tubes 3 including the first case.

As shown in FIG. 6, in the first case, when the slant angle is larger than  $35^\circ$ , the thermal stress became substantially  $15 \text{ N/mm}^2$  or lower, which proves that the combination is capable of adequately enduring a normal usage of a heat exchanger.

Further, as shown in the same view, the same results were obtained by slant angles calculated by the formula 1 for the respective combinations regarding the combinations of other various sheet plates and tubes.

Note that in this first embodiment, the vulnerable portions 2e bend to absorb the thermal stress of the connection portions against the tubes, thereby contributing to alleviation of the thermal stress.

FIG. 7 shows measurement results of performing heat and impact durability tests in which warm water and cool water are repeatedly made to flow through combinations of tubes (thickness: 0.18 mm) made thinner than conventional ones and sheet plates 2 with various thicknesses.

As shown in FIG. 7, in the first case, when the slant angle is larger than  $35^\circ$ , the combination passed the durability tests of approximately 7000 times, which proves that the combination is capable of adequately enduring a



normal usage of a heat exchanger.

Further, as shown in the same view, the same results were obtained by slant angles calculated by the formula 1 for each combination regarding combinations of other sheet plates having various thicknesses.

Furthermore, as shown in FIG. 8, a correlation of optimum slant angles of the connection portions of specific sheet plates and tubes can be graphed, which enables to easily obtain the optimum slant angle for making the sheet plates 2 and the tubes 3 thinner to thereby prevent cracking/breaking of the tubes due to the thermal stress of the connection portions.

Therefore, for the core structure H of the heat exchanger in this embodiment, the formula 1 can be used to easily obtain an optimum slant angle of the connection portions 2c according to an average thickness of the connection portions including the vulnerable portions of the sheet plates 2 and the thickness of the tubes 3, and in this case, cracking/breaking of the tubes 3 due to the thermal stress of the connection portions 2c can be prevented, so that the durability of tubes 3 can be increased as compared to conventional tubes.

Further, by the formula 1, a correlation among the slant angle of the connection portions 2c, the thickness of the sheet plates 2, and the thickness of the tubes 3 can be comprehended to thereby facilitate making the sheet plates 2 and the tubes 3 thinner.

FIG. 9 shows portions in the vicinity of connection portions 2c of a core structure of a heat exchanger according to a second embodiment of the present invention. For these connection portions 2c, a bottom portion 2g is formed as a flat portion.

In this case, similarly to the case described with FIG. 5, an origin O is taken

at a position in between adjacent tubes 3 and 3 and in contact with the bottom face of the sheet plate 2 to measure a slant angle  $\theta$ .

5 Thus, even when the connection portions 2c are formed to have a flat portion, the formula 1 is satisfied.

10 In the foregoing, the embodiments of the present invention have been described, but the specific structure of the present invention is not limited to these embodiments. The present invention includes any change of design in the range not departing from the gist of the invention.